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(71) Applicant: MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

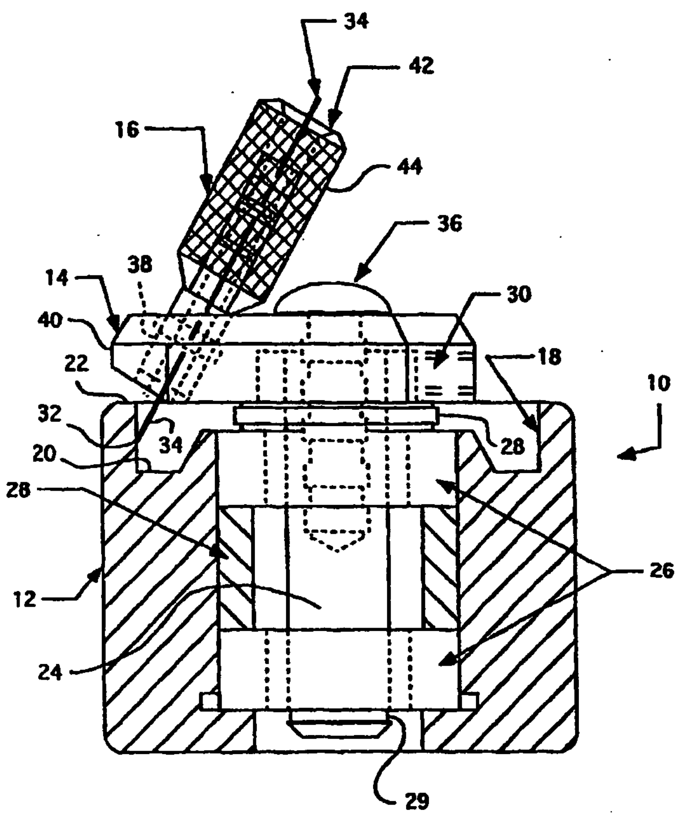
(72) Inventors: CARPENTER, James, B.; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). PATTERSON, Richard, A.; P.O. Box 33427, Saint Paul, MN 55144-3427 (US). PEPIN, Ronald, P.; P.O. Box 33427, Saint Paul, MN 55144-3427 (US).

(74) Agents: MUSGROVE, Jack, V. et al.; Office of Intellectual Property Counsel, Minnesota Mining and Manufacturing Company, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

(54) Title: BEVELING TOOL FOR OPTICAL FIBERS

(57) Abstract

A tool (10) for generating a beveled end (32) on an optical fiber (34). The tool (10) comprises a base (12) having an abrasive surface (18), and an arm (14) supporting an adapter (16) which secures the terminal portion of the fiber (34) to be beveled. The arm (14) is attached to the base (12) in such a manner as to provide relative translational movement between the arm (14) and the abrasive surface (18). In one embodiment, the abrasive surface (18) is found along a wall of a circular channel (20) formed in the upper end (22) of the base (12). In other embodiments, the abrasive surface (18) is generally planar, either formed directly on the base (12), or formed on a platter which is attached to the base (12). A motor may be provided to induce movement of the platter, via a crank arm or pulley system. The operator may impart a precise bevel (i.e., a predictable included angle and end face diameter) by setting the length of the fiber extending from the adapter, and by rotating the arm or platter a certain number of turns. When the fiber adapter (16) is oriented orthogonal to the abrasive surface (18), but the length of the fiber extending from the adapter (16) is greater than the distance between the adapter (16) and the abrasive surface (18), the fiber (34) bows near its terminal end (32), and its resilience provides the force needed to grind down the periphery of the end face. The tool (10) may be designed to avoid rotation of the adapter (16) (from an absolute frame of reference), thereby precluding unnecessary torsional stress in the fiber (34).



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BEVELING TOOL FOR OPTICAL FIBERS

Background of the Invention

1. Field of the Invention

The present invention generally relates to optical fibers, and more particularly to the preparation of a terminal end of an optical fiber which is to be connected to another fiber or an optical device.

2. Description of the Prior Art

In recent years, optical fiber has surpassed copper as the preferred medium for telecommunications. Optical connectors and splices are used to interconnect fiber optic cables, and to terminate fibers at electro-optical devices. A "connector" often refers to a device which allows repeatable engagement and disengagement of the cable, while a "splice" typically refers to a device which is used for the permanent attachment of two cable ends. These terms should not, however, be construed in a limiting sense as used herein since the present invention is applicable to all classes of fiber optic interconnection devices.

There are several different kinds of connectors and splices, including ferrule or biconic connectors, and fusion or mechanical splices. In each of these devices, the terminal end of the fiber is physically prepared in order to optimize transmission of the signal at the interface between adjacent fibers (or between a fiber and an electro-optical component). For example, the fiber ends are usually cleaved and/or polished. It has also been found that beveling (chamfering) the end face of the fiber may improve connector performance. As shown in Figure 1A (in which the angles of the end faces are exaggerated for purposes of illustration), if the end faces are not perfectly parallel, there will be a slight gap at the center of the fibers, where the entire signal travels along the innermost core. This is usually the case when the fibers are simply cleaved and not polished.

As further illustrated in Figure 1B, signal transmission usually improves (insertion loss is lower)

with beveled fibers, in part due to the smaller longitudinal séparation s at the fiber centers. In Figure 1B, the fibers have been cleaved and beveled, but not polished. In this regard, the term polishing refers to grinding the entire surface of the fiber end face, particularly the central portion thereof. In contrast, beveling (or chamfering) only grinds the periphery of the fiber or, alternatively, leaves a central portion of the end face untouched. There are also fewer problems when inserting a beveled fiber into a connector or splice. For example, the fiber is less likely to skive or scrape material from a splice element formed of a soft material, such as aluminum.

The primary method in the prior art for imparting a bevel to a fiber is depicted in Figure 2. In that method, an abrasive pad **1** is mounted on a grinding wheel **2** attached to a spindle or shaft **3**. A collet **4**, which is spatially fixed with respect to wheel **2**, holds the fiber **5** to be beveled. Collet **4** is provided with a gear **6** which causes fiber **5** to rotate as it contacts pad **1**. This device has several significant disadvantages. Since the collet is fixed with respect to the grinding wheel, it is very limited in the bevel geometry it can generate. Specifically, since the distance from collet **4** to pad **1** is constant, the length of fiber **1** extending from collet **4** is likewise constant. Also, the angle of inclination of collet **4** is fixed. These limitations preclude wide selection of end face diameters and included angles of the bevel surface. Additionally, rotation of collet **4** via gear **6** induces torsional stress on that portion of the fiber leading away from the device, which could damage the fiber and even lead to breakage.

Another grinding method similar to beveling is taught in U.S. Patent No. 4,766,705, but that technique is considered generally unsuitable for most connection applications since it produces a chiseled end face rather

than a conical bevel.

In some instances, the performance of beveled (unpolished) fibers exceeds that of polished fibers. Beveling may eliminate the time and expense associated with polishing, but it is of less overall benefit if the beveling process is more demanding than polishing. It would, therefore, be desirable and advantageous to devise a simple apparatus for quickly imparting a beveled finish to the end face of an optical fiber. Such an apparatus should, however, overcome the limitations of the device shown in Figure 2 relating to the geometry of the bevel and torsional stress on the fiber.

Summary of the Invention

The present invention provides a bevel generating tool generally comprising a base having an abrasive surface, an arm rotatably mounted to the base, and an adapter securing the terminal portion of the optical fiber, the adapter being removably attached to the arm. The abrasive surface is formed on the base such that the surface is oriented at a non-orthogonal angle with respect to the axis of rotation of the arm, i.e., the abrasive surface is either parallel with this axis, or oriented at an oblique angle with respect thereto. The abrasive surface may be formed along a wall circular channel formed in the upper end of the base, the wall being either generally cylindrical or generally conical in shape. In the preferred embodiment, the arm has a hole therein for receiving the adapter, and the hole is skewed with respect to the plane defined by the arm. The arm may be fixed to a shaft which is rotatably mounted to the base, and its effective length may be adjusted. Optical fibers having beveled end faces exhibit improved performance in both multimode and singlemode applications, and in both discrete (single) and multifiber connectors and splices. Beveled fibers may be used with or without index matching gel. The beveling process is

simple and may require less than a minute to complete per fiber. Beveling may be performed manually or with a motorized tool.

Brief Description of the Drawings

The novel features and scope of the invention are set forth in the appended claims. The invention itself, however, will best be understood by reference to the accompanying drawings, wherein:

Figure 1A is a side elevational view of the interface between two optical fibers having cleaved end faces;

Figure 1B is a side elevational view of the interface between two optical fibers having beveled end faces;

Figure 2 is a side elevational view of a prior art fiber beveling machine;

Figure 3 is a sectional view of one embodiment of the optical fiber beveling tool of the present invention;

Figure 4 is a top plan view of the beveling tool of Figure 3, with the fiber adapter omitted;

Figure 5 is a front elevational view of another embodiment of the optical fiber beveling tool of the present invention;

Figure 6 is a front elevational view of the beveling tool of Figure 5, but the adapter arm has been rotated 90° to illustrate the fiber bow;

Figure 7 is a partial sectional view along lines 7-7 of Figure 5, depicting angle polishing of the previously beveled fiber;

Figure 8 is a sectional view of an alternative abrasive surface for the embodiment of Figure 4;

Figure 9 is top plan view of yet another embodiment of the optical fiber beveling tool of the present invention;

Figure 10 is a sectional view along lines 10-10

of Figure 9;

Figure 11 is sectional view of an alternative fiber adapter;

Figure 12 is a sectional view of still another embodiment of the optical fiber beveling tool of the present invention;

Figure 13 is a top plan view of the beveling tool of Figure 12, depicting its cover assembly;

Figure 14 is a top plan view of the tool of Figure 12, with the cover assembly removed, illustrating movement of the abrasive media platter and cam slide; and

Figure 15 is a sectional view of a further embodiment of the optical fiber beveling tool of the present invention, similar to that of Figure 12.

Description of the Preferred Embodiment

With reference now to the figures, and in particular with reference to Figures 3 and 4, there is depicted one embodiment **10** of the fiber beveling tool of the present invention. Tool **10** is generally comprised of a base **12**, a rotating fiber adapter arm **14**, and a handheld fiber adapter **16**. Base **12** has an abrasive surface **18** formed thereon for grinding the fiber end periphery during the beveling process. In the embodiment of tool **10**, abrasive surface **18** is defined by the outer wall of a circular channel **20** formed at the upper end **22** of base **12** (it could also be formed along the inner wall of channel **20**). The abrasive nature of surface **18** may be created using either loose particle abrasives or micro-abrasive film adhesively secured to the outer wall of channel **20**. One film appropriate for this use is the micro-abrasive paper sold by Minnesota Mining and Manufacturing Co. (3M --assignee of the present invention) under the designation Imperial Lapping Film (with grit sizes varying from 0.3 μm to 5 μm; grit material may include aluminum oxide, cerium oxide, silicon carbide and diamond). Base **12** may be constructed of any durable material, such as

polycarbonate or aluminum.

Arm **14** is fixed to a shaft **24** which is rotatably mounted in base **12** by means of bearings **26**, spacers **28** and C-clip **29**. A set screw **30** may be used to adjust the effective length of arm **14**, i.e., the proximity of the end **32** of fiber **34** to surface **18**. In an equivalent design, arm **14** could be rotatably mounted to base **12** without the need for a rotating shaft. Arm **14** is releasably attached to shaft **24** by retainer screw **36**. Arm **14** and shaft **24** may also be constructed of any durable material, preferably a metal such as aluminum or stainless steel.

Arm **14** has a hole **38** therein near its distal end **40**, for receiving fiber adapter **14**. Hole **38** does not extend normal to the plane of arm **14**, but is slightly skewed. In this manner, the portion of fiber **34** immediately exiting adapter **16** is oriented at an oblique angle with respect to surface **18**, and the resilient nature of optical fiber **34** causes it to bow near end **32**. This resilience also maintains end **32** in forcible abutment with the abrasive media on surface **18**. Adapter **14** secures fiber **34** by means of an elastomeric gripping collet which may be conveniently attached to an implement which facilitates manual grasping. In Figure 3, a polyurethane collet **42** (preferably having a durometer of about 50-80 Shore D) is inserted in an empty field mount ST ceramic connector **44** (after the collet has been threaded with the fiber). A bearing **46** is provided in hole **38** to allow rotation of fiber adapter **16** with respect to arm **14**. It should be understood, however, that adapter **16** does not rotate from an objective perspective, since it is arm **14** which is actually rotating. In other words, as the user is holding adapter **16** and indirectly pushing arm **14** to cause it to rotate, adapter **16** moves in a circle back to its original position without rotating the fiber. Those skilled in the art will appreciate that, since this movement does

not rotate the fiber, it does not induce any severe torsional stress which could damage or break the fiber.

In tool **10**, and in each of the following embodiments of the present invention, there is relative translational motion between the fiber adapter and the abrasive surface. In contrast, there is no translational movement between the adapter and abrasive disk of the prior art tool of Figure 2, even though they each individually rotate.

With tool **10**, fiber preparation is reduced to a few simple steps. First, the fiber is stripped and cleaved using conventional methods. The cleaved fiber is next inserted into collet **42** of hand-held adapter **16**; the length of fiber extending past adapter **16** may be measured and set (as explained further below) if a specific bevel profile is desired. Adapter **16** is then inserted through bearing **46** in hole **38**, positioning fiber end **32** against abrasive surface **18**, as depicted in Figure 3. Arm **14** may be adjusted towards or away from surface **18** using set screw **30**, increasing or decreasing the amount the fiber is forced into surface **18**. This adjustment affects the material removal rate as well as the included angle of the bevel.

The end face diameter **d** and the included angle **A** of the bevel (see Figure 1B) are the two main parameters of a beveled cylinder. These parameters are theoretically adjustable within a wide range, depending upon the size of the fiber. While tool **10** is somewhat limited in the ranges it can generate, the other embodiments of the present invention described below may be used to produce wide ranges in beveling, from just lightly chamfering the edge, to grinding away nearly all of the end face except for the core. The bevel profiles illustrated in the drawings should therefore not be construed in a limiting manner. For example, single mode fibers having an outside diameter of 125 μm (0.005") and a concentric, 7.6 μm (0.0003") diameter core were beveled

with end face diameters ranging from 117 μm (0.0046") to 15.2 μm (0.0006"). Consistent repeatability was achieved to within ± 7.6 μm (0.0003"). Included angles for the 125 μm fibers ranged from 40° to 160°, although the range of included angles for tool **10** was about 70° ± 10°. The included angle is ultimately limited by the length of the fiber that can extend beyond the fiber adapter (in tool **10**, this limit could be increased by making channel **20** deeper and adjusting the angle of adapter **16**). With each of the novel beveling tools described herein, the included angle can be controlled with excellent repeatability by accurately measuring the length of the fiber, such as by using a length setting fixture (not shown), similar to a ruler or a micrometer. Concentricity of the end face of the fiber is maintained with respect to the outside diameter thereof.

Once adapter **16** is positioned, it is grasped between the thumb and forefinger and used to rotate arm **14** in a clockwise or counterclockwise motion. As explained above, the fiber does not rotate as it is clamped in collet **42** secured to adapter **16** which is held by the user. This causes the entire fiber edge periphery to come into contact with abrasive media upon each complete rotation of the adapter arm, consequently generating a conical bevel. As explained below, a specific number of arm rotations results in a particular end face diameter. After the desired number of rotations, adapter **16** is removed from arm **14**, fiber **34** is removed from collet **30**, and its end is cleaned using conventional methods. Typical times spent rotating arm **16** range from three to five minutes. Insertion and removal of fiber **34** from collet **30**, and cleaning of the fiber, take about a minute.

There are many benefits that can be obtained by generating a bevel on the end of an optical fiber. The first is removal of end face surface imperfections caused by the cleaving process, particularly protruding defects

at the edge which are common among cleaved fibers. Another benefit is the reduction of fiber end face separation as shown in Figures 1A and 1B. Yet another benefit is the reduction in end face surface area which may improve physical contact between interconnected fibers. As noted above, this also allows smoother insertion into fiber optic devices. A related benefit is the improved edge strength of a beveled end face, since there is more supporting glass behind the edge, i.e., the chamfer surface is frusto-conical. It should be understood that, while the beveling depicted in the drawings is generally conical, it need not be, e.g., the bevel profile could be rounded rather than straight.

Besides its ease and quickness of use, tool **10** has several other advantages. It is relatively lightweight and may be very compact, which facilitates transportation and storage. While the dimensions of tool **10** may vary considerably depending upon the particular applications, the following approximate dimensions are deemed exemplary for beveling most conventional fibers used in telecommunications. Base **12** has a diameter of 5.1 cm (2"), and is 4.4 cm ($1\frac{3}{4}$") high, from the bottom of base **12** to the top of adapter arm **14**. Hole **38** is oriented at a 30° angle with respect to the normal of arm **14**, i.e., with respect to surface **18**.

Another advantage of tool **10** is that it is manually driven and requires no power source. Of course, means could be provided to motorize arm **14** (and prevent rotation of adapter **16**), which would require that tool **10** also include a battery (or solar cells) for portability, or have a transformer or other means for converting standard 110 volt AC power. Other manual techniques could be used to drive arm **14**, such as a spring wound motor, flywheel, turbine, etc.

Referring now to Figures 5-7, an alternative embodiment **50** of the present invention may be used to impart a bevel to an optical fiber. Tool **50** has a body

52 which houses a rotating shaft supported by bearings in a manner similar to that shown in Figure 3. Body **52** also acts as a handle for the tool. A disk **54** is attached to body **52** at one end thereof, the disk having another abrasive surface **56**. An arm **58** adjacent disk **54** is attached to the rotating shaft inside body **52**. Arm **58** has a hole therein to rotatably support an adapter **60** which is similar to adapter **14**. As shown in Figure 6, a fiber held in adapter **60** will undergo the same bowing toward its end where it contacts abrasive surface **56**. A gage may be used to set the length of fiber extending beyond adapter **60** (the fiber set length). The amount of bowing of the fiber determines its included angle and the amount of force imparted, which determines the material removal rate at the periphery. Arm **58** may be moved clockwise or counterclockwise. Operation is essentially identical to that with tool **10** and, as with tool **10**, the fiber itself does not rotate or twist when using tool **50** since adapter **60** is free to rotate in arm **58**, and it is held by the user during movement of arm **58**. With every complete rotation of the pivot arm, the complete end periphery of the fiber contacts the abrasive media. A conventional counter **62** may optionally be provided to track the number of revolutions of arm **58**. Counter **62**, which has a reset button **64**, is attached to body **52** by a bracket **66**.

Figures 5-7 also depict the optional provision of a second fiber adapter **70** which may be seated in a second hole of arm **58**. Adapter **70** may be used to impart an angled end face to a fiber which has already been beveled. Angle polishing the end face of a fiber is known to minimize the adverse effects of back reflections which occur when a signal traverses the fiber end face. In this embodiment, the outer portion of abrasive surface **56** may be coarser for beveling (e.g., 5 μm grit), than the inner or central portion which is finer for polishing (e.g., 0.3 μm grit).

After a fiber has been beveled as described above, it may be moved from the outermost (beveling) hole on arm **58** to the innermost (polishing) hole. In this regard, adapter **70** should be compatible with both of these holes so that the user does not have to remove the fiber from one adapter and place it into another. The fiber set length is adjusted, however, when moving the adapter from the beveling hole to the polishing hole, by the difference in height where adapter **70** rests on arm **58**. This adjustment (decreasing the fiber set length to slightly greater than the distance from the adapter to surface **56**) changes the pitch of the fiber end, and results in removal of a portion of the end face rather than the periphery. In order to polish a flat angled finish, it is necessary to fix adapter **70** to arm **58** (nevertheless, tool **50** can still, if desired, avoid actual rotation of the fiber by moving the entire body **52** and disk **54** in a circular motion while maintaining adaptor **70** fixed; such manipulation of tool **50** is facilitated by its hand-held nature). Adapter **70** may be fixed on arm **58** by any convenient means, such as keying it with a spline which mates with a corresponding groove formed in the polishing hole of arm **58**, or providing other mechanical polarizing means. A ring or bushing may be placed about adapter **70** to be gripped with fingers if arm **58** is to rotate while body **52** is stationary.

The outermost hole of arm **58** could also be used to polish an angled end face, but the present invention is primarily directed to a fiber beveling tool and so, in the preferred embodiment of tool **50**, the outermost hole in arm **58** is not design for fixed (keyed) attachment. Use of the optional polishing adapter could also be designed into a modified version of tool **10**.

In the embodiment of Figures 3 and 4, the effective orientation of surface **18** (i.e., the orientation of the tangent plane defined at any point of contact between fiber **34** and cylindrical surface **18**) is

parallel to the axis of rotation of arm **14**. In contrast, tool **50** orients abrasive surface **56** perpendicular to the axis of rotation of arm **58**. Those skilled in the art will appreciate that either of the tools **10** or **50** could alternatively provide an abrasive surface **18** which was oriented at a non-orthogonal angle but still not parallel to the axis of rotation of arm **14**, i.e., at an oblique angle. For example, a frusto-conical surface **68** could be provided as shown in Figure 8, wherein the axis of the cone coincides with the rotating shaft. In a modified version of tool **10**, channel **20** could be formed in an insert element which is removably positioned in the upper end of base **12**, and a plurality of such inserts interchangeably used to provide abrasive surfaces at different angles. There are, however, some advantages in using flat disk **54** to support the abrasive surface. There are more commercially available abrasive pads which are the appropriate size and shape for a disk, and they are easily replaced. There is also more useable abrasive media, particularly if the length arm **58** is adjusted to use different ring areas over the radius of the pad.

As with tool **10**, tool **50** is both lightweight and compact. While its dimensions may also vary, the following approximate dimensions are considered exemplary for tool **50**. Its overall length (from the tip of counter **62** to the top of arm **58**) is 23 cm (9"), with an additional 2.5 cm (1") for the fiber adapter. The abrasive disk is 10 cm (4") in diameter.

Another hand-powered fiber beveling tool made in accordance with the present invention is shown in Figures 9 and 10. Tool **72**, however, is intended for bench use. It includes a base **74** having another rotatably mounted shaft **76**, with another arm **78** attached to shaft **76**. Operation of tool **72** is similar to that of tool **50**. Tool **72** may be designed for use with a different type of adapter **80** depicted in Figure 11, which grips the fiber more securely than adapter **16**. Different

adapters, each having the same outer dimensions, may be used for different fibers, i.e., 250 μm and 900 μm fibers, or even fiber ribbons, with only the inner fiber passageway being different. In this regard, those skilled in the art will appreciate that the beveling tools described herein may be used to bevel multi-fiber ribbons as well as discrete fibers. A fiber ribbon will not flex (bow) in the identical manner as a discrete fiber (i.e., it is stiffer along its transverse dimension), but a satisfactory bevel may still be formed, although it may be oval about the periphery rather than perfectly circular. In this manner, the different adapters can fit into a common nest in arm **78**. Of course, adapter **80** could also be used with the other beveling tools described herein.

Adapter **80** has a body **82** with a collet portion **84** and a cap **86** movable on the collet between a raised, open position and a lowered, closed position. An inwardly extending annular flange **88** formed in one end of cap **86** provides a friction fit for both positions, by seating in one of two grooves on either side of an annular ridge **90** formed at the juncture of collet **84** and body **82**. In the preferred embodiment, cap **86** moves about 2 mm (0.08") between the open and closed positions. Cap **86** and body **82** are constructed of any resilient material, preferably a polymer such as DELRIN™, an acetal polymer available from E.I. duPont de Nemours of Wilmington, Delaware. Collet **84** has a hole therethrough for receiving the fiber, and the entrance end of collet **84** has several slots extending from edge to edge through the fiber hole, approximately one-third the length of the adapter **80**. The outer surface of collet **84** and the inner surface of cap **86** are conical or tapered, so that moving cap **86** to its lowered position creates a confining pressure about collet **84**, collapsing it partially about the slots, thereby compressing the fiber and securing it in the adapter. Closing adapter **80** does not affect the

position of the fiber which is important since the fiber set length is measured with a gage prior to closing. In an adapter for 250 μm fiber, the fiber hole through collet **84** and body **82** is preferably about 280 μm (0.011") in diameter. An adapter for 900 μm fiber would have a hole about 1 mm (0.04") in diameter. The hole through a fiber ribbon adapter (e.g., for a 12-fiber ribbon) would be more of a slot, with a width of about 280 μm (0.011") and a length of about 3.2 mm (0.125"). Of course, cap **86** also has a hole therethrough, preferably tapered, for insertion of the fiber and alignment with the fiber passageway in collet **84**. The overall height of adapter **80** is approximately 3.2 cm (1¼"); the lower body has a diameter of about 0.6 cm (¼"), and the cap has a diameter of about 1 cm (0.4"), with a flange width of 1.5 cm (0.6"). The following approximate dimensions are considered exemplary for tool **72**. Base **74** is 10.8 cm (4¼") in diameter, and 5 cm (2") high, although the overall height (from the bottom of base **74** to the top of the cam clamp mentioned below) is 9.9 cm (3.9"). Arm **78** is 10.5 cm (4.13") long.

A flange **92** is formed on body **82** as a reference for the fiber set length, and to attach adapter **80** on arm **78**. In the preferred embodiment of Figures 9 and 10, adapter **80** is secured to arm **78** by spring-loaded locking clamps **94**. Clamps **94** pivot about shoulder screws **96** and are adjacent a plate **98**, forming part of arm **78**, having a slot **100** therein defining a track for adapter **80**. With this construction, an adapter **80** may be inserted into clamps **94** by sliding the adapter along plate **98**, in slot **100** (from the left side of Figure 9), to nest area **102**. By sliding adapter **80** onto arm **78** in this manner, the end of the fiber slides onto and across abrasive surface **104**. This minimizes possible damage to the fiber end face which might otherwise occur if the adapter were moved downward onto nest area **102**, and which would require re-cleaving.

When adapter **80** is in nest **102**, the ends of clamps **94** overlie flange **92** and restrict upward motion (accidental removal) of adapter **80**, although there is sufficient clearance between the clamps and flange **92** to allow rotation of adapter **80** as arm **78** rotates. After the fiber has been beveled, adapter **80** may be upwardly removed by squeezing the handle portions of clamps **94**, thereby retracting the clamps from over flange **92**.

Another optional feature of tool **72** is the ability to index the adapter arm, i.e., adjust its length, which allows greater use and life of the abrasive sheet on surface **104**. In the preferred embodiment of tool **72**, this is achieved by machining multiple slots **106** in an extension **108** of arm **78**, the slots being perpendicular to the axis of shaft **76**. A pin **110** smaller in diameter than slots **106** is pressed though shaft **76** to locate arm **78** in one of many indexed positions. A cam clamp **112** attached to the top of shaft **76** has a radius cam surface **114** which applies and releases clamping forces to adapter arm **78** through a bushing **116**. This mechanism allows quick indexing of arm **78**. Cam clamp **112** is shown in its clamping position, with the release position indicated with dashed lines. A pin **118** retains cam clamp **112** on shaft **76**, but can be removed to quickly and easily disassemble clamp **112**, bushing **116** and arm **76** from shaft **76** to permit changing of the abrasive sheet at surface **104**.

In a variation (not shown) of tool **72**, the abrasive media is formed on a disk which may also rotate about shaft **76**. The disk is connected by a gear train to shaft **76**, such that movement of arm **78** causes counter-rotation of the disk, speeding up beveling time.

With further reference to Figures 12-14, a motorized embodiment **120** of the fiber beveling tool of the present invention is presented. Tool **120** uses the same principles as the foregoing tools to bevel the fiber end without twisting the fiber. Tool **120** includes a base

122 housing a motor **124** (preferably having a 280 rpm output at 12 volts). Base **122** should also house a power source for motor **124**, i.e., a battery or a 110 volt to 12 volt converter (not shown). A coupling **125** attaches the shaft **126** of motor **124** to a crank arm **128**. The upper end of crank arm **128** is rotatably mounted to a platter **130** by means of a bearing **132** inserted in a socket **134** formed in the lower surface of platter **130**. Movement of platter **130** is limited by a sliding plate **136** having a generally rectangular cutout **138** therein, the cutout surrounding socket **134**; the outer wall of socket **134** is accordingly generally square in shape. Movement of sliding plate **136** is in turn limited by slide retainers **140**, which allow sliding movement of plate **136** in only one direction, and by the inner walls **142** of base **122**. In this manner, platter **130**, which supports the abrasive media, may move in an orbiting fashion about the axis of shaft **126**, but platter **130** does not necessarily rotate due to bearing **132**. Crank arm **128** draws a circle about 3.8 cm (1.5") in diameter.

A cover assembly **144** shown in Figure 13 overlies base **122** and receives a plurality of adapters **80**. Cover assembly **144** includes a cover plate **146** having a plurality of slots **148** similar to slot **100** in arm **78** of tool **72**. Cover plate **146** is generally circular and slots **148** extend radially thereon from the periphery of plate **146** toward the center thereof, where each slot terminates in a nest area **150** near the center of plate **146**. In the preferred embodiment of tool **120**, cover plate **146** has eight slots, and may thus simultaneously bevel eight different fibers (more or less slots could be provided). Adapters **80** may be secured in nest areas **150** by means of a fiber adapter lock **152** rotatably attached to plate **146** at the center thereof. Fiber adapter lock **152** has a plurality of spokes or fingers **154** which extend toward nest areas **152**, but the fingers are spaced widely enough to allow upward removal of adapters **80** when lock **152** is

in its open position. By slightly twisting lock **152** to its closed position, one of the fingers **154** overlies each nest area, securing the adapters by retaining flanges **92** thereof. As with the foregoing embodiments, the fibers do not rotate during the beveling process, i.e., fiber adapter **80** does not rotate when platter **130** is orbiting. Bevels were generated on fibers within 15 seconds with this tool.

The following approximate dimensions are considered exemplary for tool **120**. Base **122** is 22 cm (8.6") in diameter, and 16.8 cm (6.6") high. Cover **146** is 18.7 cm (7.35") in diameter. The overall height of tool **120** (from the bottom of the base to the top of the cover) is 21 cm (8.4"). There is a 6.4 cm (2½") spacing (centerline to centerline) between adjacent fiber adapters.

Another motorized embodiment **160** of the fiber beveling tool of the present invention is illustrated in Figure 15. Tool **160** is very similar to tool **120**, and includes a base **162** housing a motor **164** which may be coupled, via reduction gears, to a shaft **166**. Base **162** of tool **160** may also house conventional components (not shown) related to motor **164**, such as a battery, speed selector switch, and timer circuit. Rather than using a sliding cam plate, however, tool **160** induces orbiting motion of the abrasive media platter **168** using a pulley system. Shaft **166** is fixed to a crank arm **170** which has a hole therein at one end for receiving the platter axle **172**, and a counterweight at the other end. Axle **172** is free to rotate in the hole due to the presence of a bearing **174** located therein. The lowest end of axle **172** passes through a pulley **176** which is coupled by a flexible belt (not shown) to another pulley **178**. Pulley **178**, which rotatably receives motor shaft **166**, is fixed to base **162** by any convenient means, such as screws. In this manner, as motor shaft **166** rotates, crank arm **174** causes platter **168** to orbit. The diameter of pulley **178**

is slightly shorter than the diameter of pulley **176** whereby platter **168** will rotate several degrees upon completion of each orbit, ensuring that the fiber end will consistently be exposed to unused abrasive media, extending the life of the abrasive sheet.

Figure 15 also illustrates the alternative use of guide rails **180** to retain the fiber adapters **80** on the cover **182** of tool **160**. As with tool **120**, cover **182** may have a plurality of slots therein for receiving the adapters. Guide rails **180** overlap a portion of the slots, with sufficient clearance to receive flange **92** of adapter **80**. This prevents the accidental upward movement of the adapter during insertion which might lead to fiber end face contact with the abrasive surface, causing damage to the end face. Guide rails **180** may be provided with integral leaf springs at the adapter nest areas to forcibly secure the adapters during the beveling operation.

The following approximate dimensions are considered exemplary for tool **160**. Base **162** is 21.6 cm (8.5") square, and its overall height is 13.5 cm (5.3"). The distance from the abrasive surface to the bottom of the fiber adapter (when it is fully inserted into the slots in cover **182**) is 7.65 mm. A user of tool **160** may generate a bevel with a desired included angle **A** and a desired end face diameter **d** for a glass fiber by adjusting the fiber set length and rotating arm the number of turns indicated in the following table. These data were gathered using a 250 μm buffered fiber (with a 10 mm strip length) and Imperial Lapping Film with a 1.5 μm grit (diamond abrasive). Platter **168** rotated at 240 orbits per minute.

SET LENGTH	BEVEL TIME	END FACE DIAMETER (± .0003)	BEVEL INC. ANGLE (± 10°)
8MM	15 SEC.	30.48μm (.0012")	150°
9MM	15 SEC.	45.72μm (.0018")	95°
10MM	20 SEC.	38.1μm (.0015")	75°
11MM	20 SEC.	50.8μm (.002")	65°
12MM	30 SEC.	43.18μm (.0017")	58°
13MM	30 SEC.	63.5μm (.0025")	45°

Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the spirit or scope of the present invention as defined in the appended claims.

CLAIMS:

1. A device for removing a portion of the end of an optical fiber along its periphery, comprising:

a base member;

adapter means for releasably securing a length of the fiber near its end, said adapter means allowing adjustment of the length;

an arm member rotatably mounted to said base member, defining an axis of rotation, said arm member having means for releasably holding said adapter means;

an abrasive surface formed on said base member proximate said arm member, said abrasive surface being oriented at a non-orthogonal angle with respect to said axis of rotation of said an arm member.

2. The device of Claim 1 wherein said abrasive surface is oriented at an oblique angle with respect to said axis of rotation of said an arm member.

3. The device of Claim 1 wherein said abrasive surface is parallel with said axis of rotation of said an arm member.

4. The device of Claim 1 wherein said arm member has an effective length, and further comprising means for adjusting said effective length of said arm member.

5. The device of Claim 1 wherein said adapter means is rotatably attached to said arm member.

6. The device of Claim 1 further comprising a shaft member rotatably mounted on said base member, said arm member being affixed to said shaft member.

7. The device of Claim 1 wherein:

rotation of said arm member defines a plane;

said adapter means includes an end portion; and

said arm member has a hole therethrough for receiving said end portion of said adapter means, said hole being skewed with respect to said plane defined by said arm member.

8. The device of Claim 1 wherein said abrasive

surface is formed along a wall of a circular channel formed in one end of said base member.

9. The device of Claim 1 wherein said adapter means includes an elastomeric collet having a slot therein for receiving the fiber.

10. The device of Claim 6 wherein said arm member is releasably affixed to said shaft member.

11. The device of Claim 7 wherein said hole has bearing means therein for rotatably supporting said end portion of said adapter means.

12. The device of Claim 8 wherein said wall of said channel is generally cylindrical.

13. The device of Claim 8 wherein said wall of said channel is generally conical.

14. A fiber beveling tool comprising:

a base having a bottom end and a top end, said bottom end being generally flat, and said base having a circular channel formed therein at said top end thereof, said circular channel having a wall supporting abrasive media, and said circular channel defining an axis;

a shaft;

bearing means rotatably mounting said shaft on said base, the location of said shaft generally coinciding with said axis of said circular channel;

adapter means for releasably securing a length of an optical fiber near its end, said adapter means having an end portion; and

an arm releasably affixed to said shaft, said arm having a hole therein for receiving said end portion of said adapter means.

15. The tool of Claim 14 wherein said adapter means includes an elastomeric collet having a hole therethrough for receiving the fiber.

16. The device of Claim 14 wherein:

rotation of said arm defines a plane; and

said hole in said arm is skewed with respect to said plane defined by said arm member.

17. The device of Claim 14 wherein said arm has an effective length, and further comprising means for adjusting said effective length of said arm.

18. The device of Claim 14 wherein said hole has means therein for rotatably supporting said end portion of said adapter means.

19. The device of Claim 14 wherein said wall of said channel is generally cylindrical.

20. The device of Claim 14 wherein said wall of said channel is generally conical.

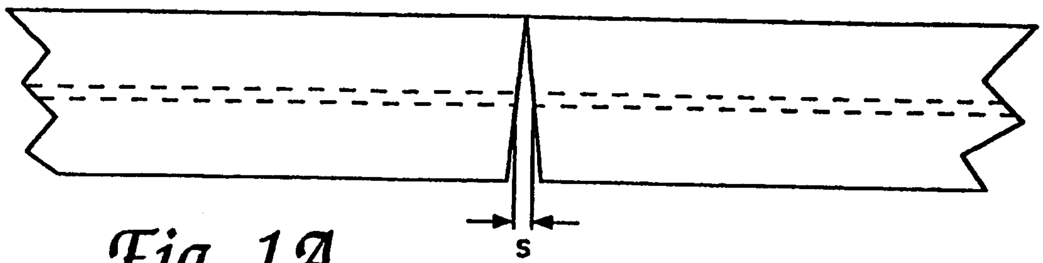

Fig. 1A

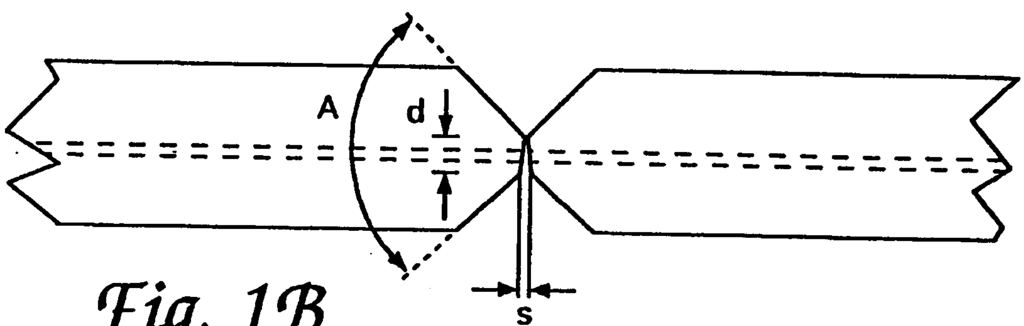

Fig. 1B

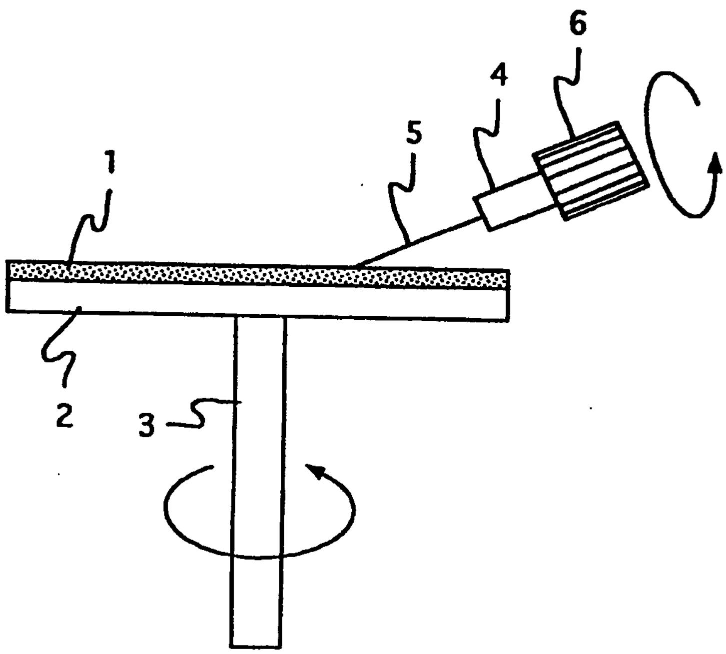

Fig. 2

PRIOR ART

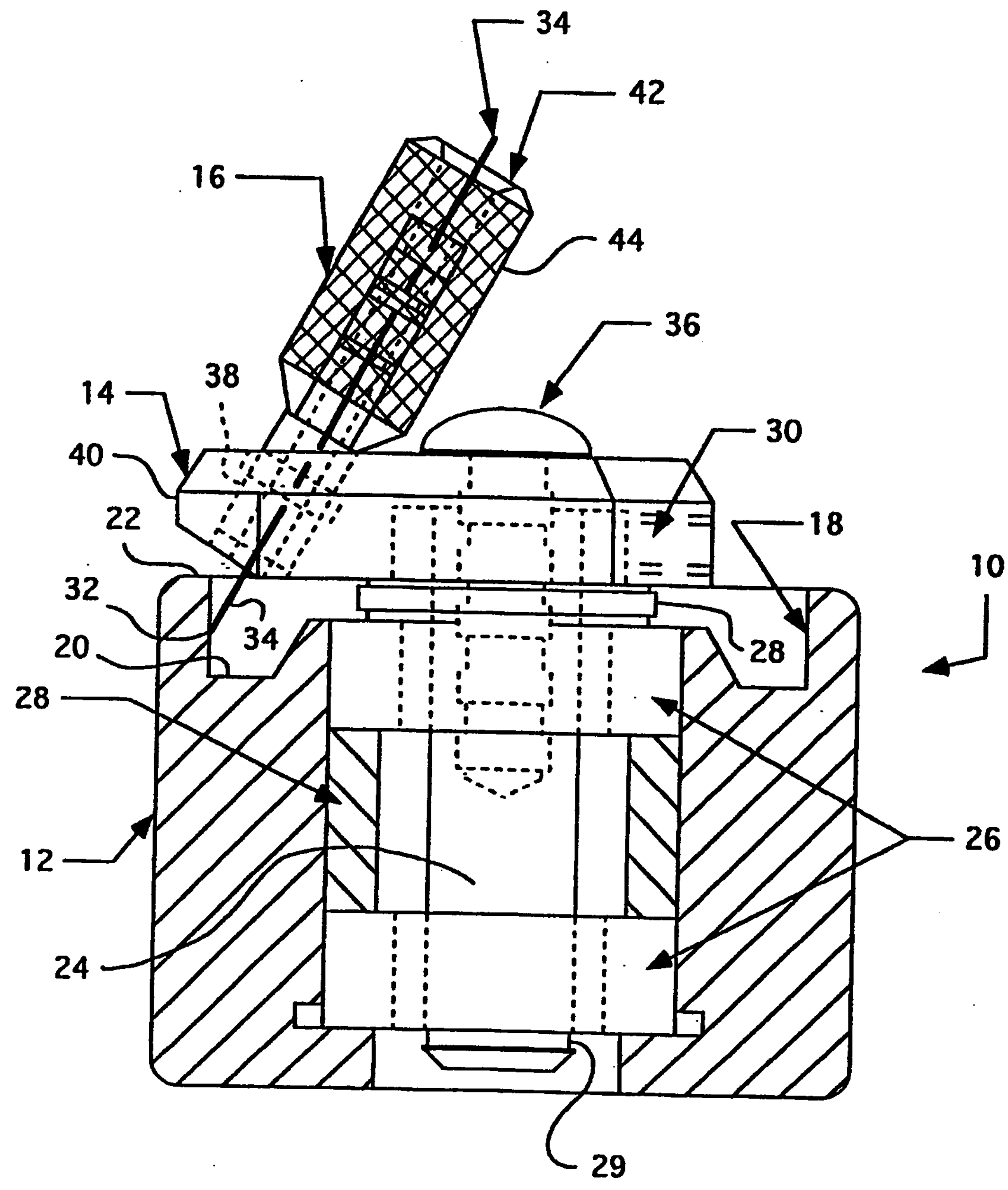

Fig. 3

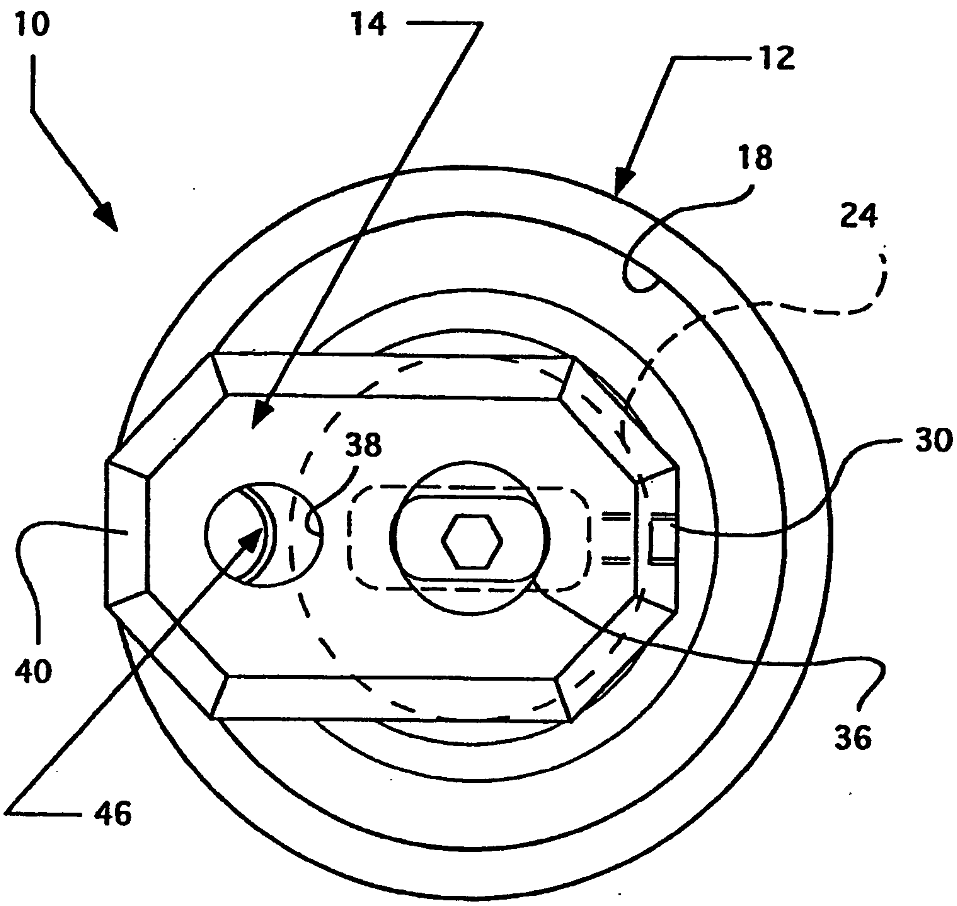

Fig. 4

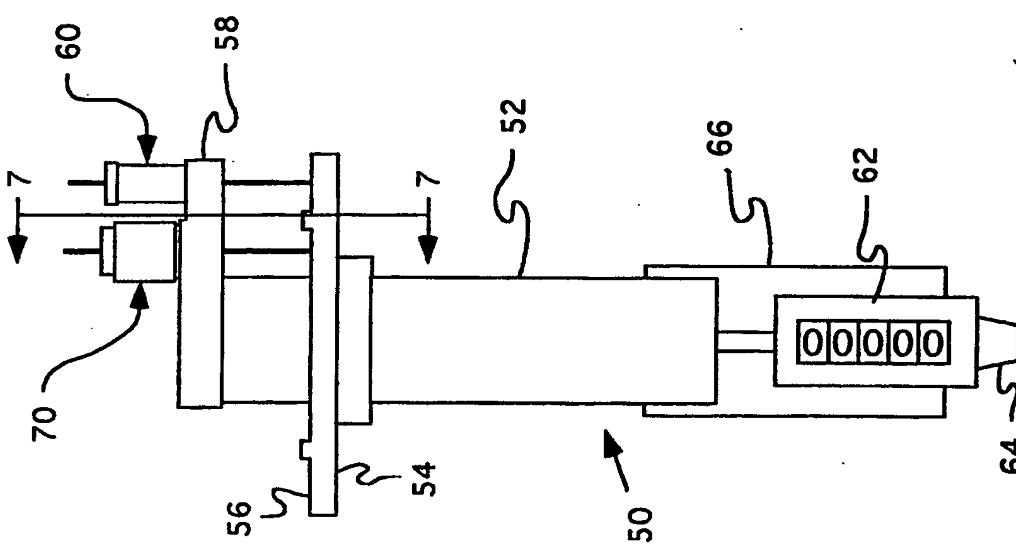

Fig. 5

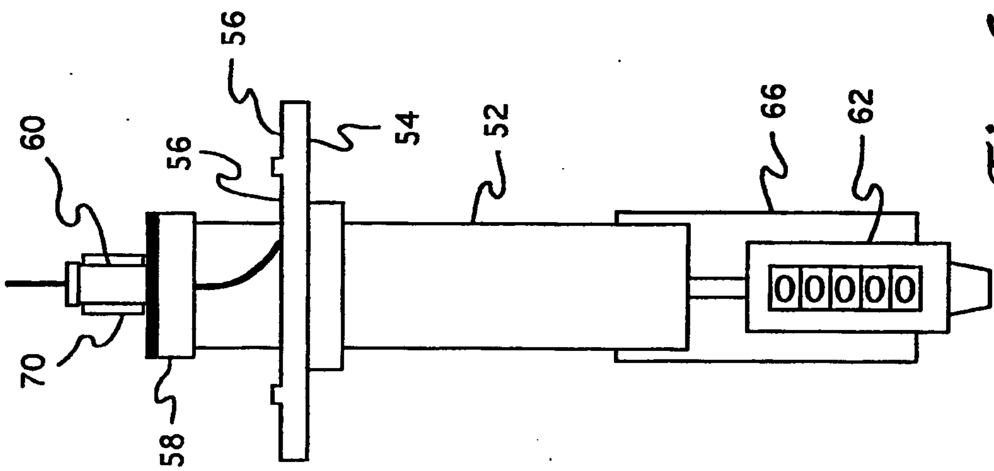

Fig. 6

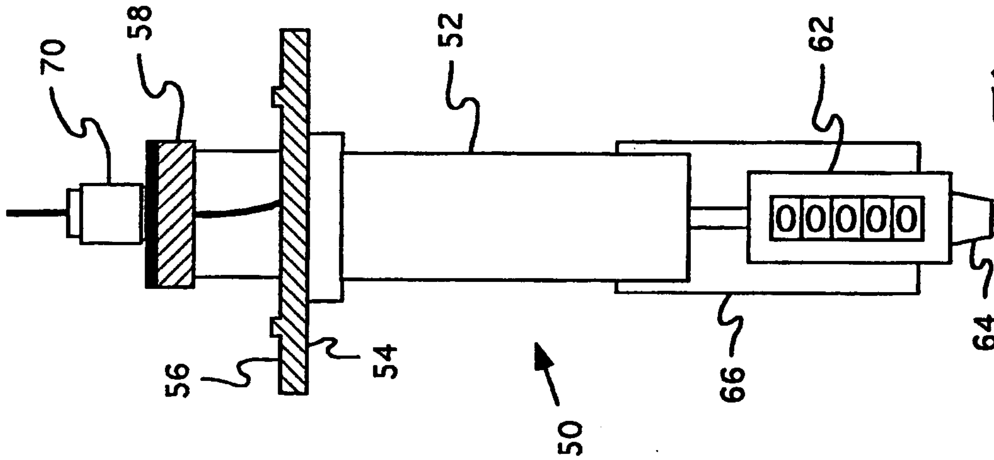

Fig. 7

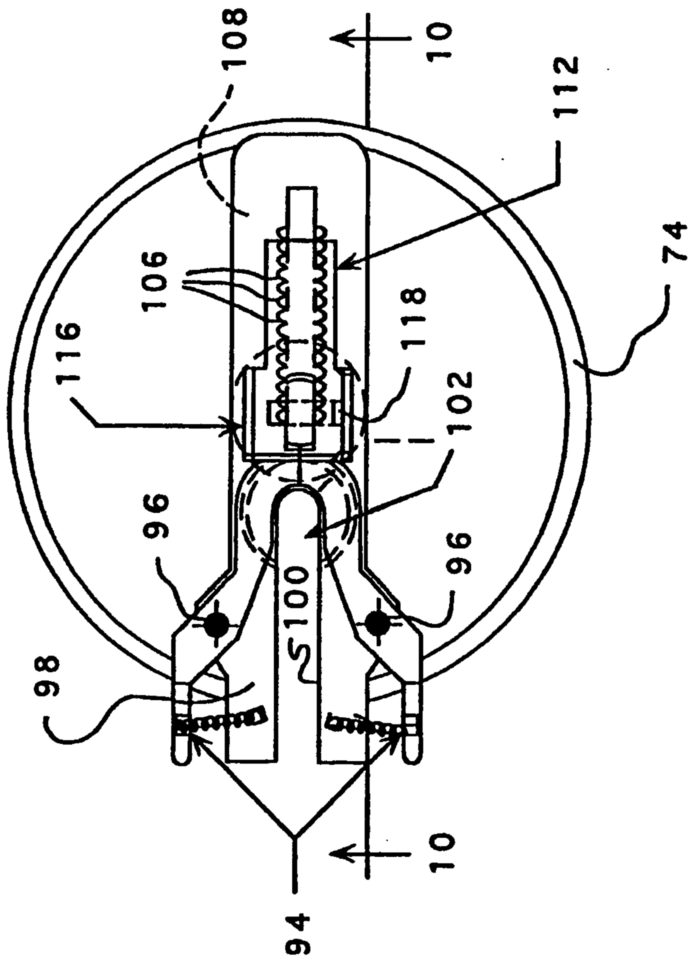

Fig. 9

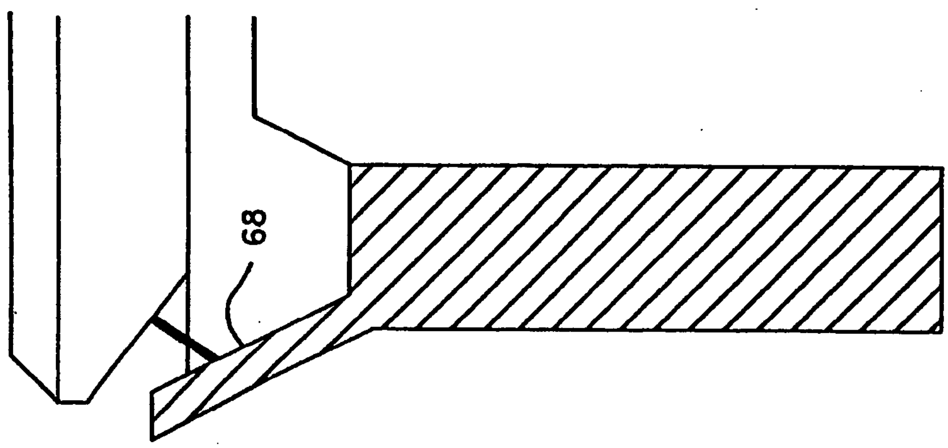

Fig. 8

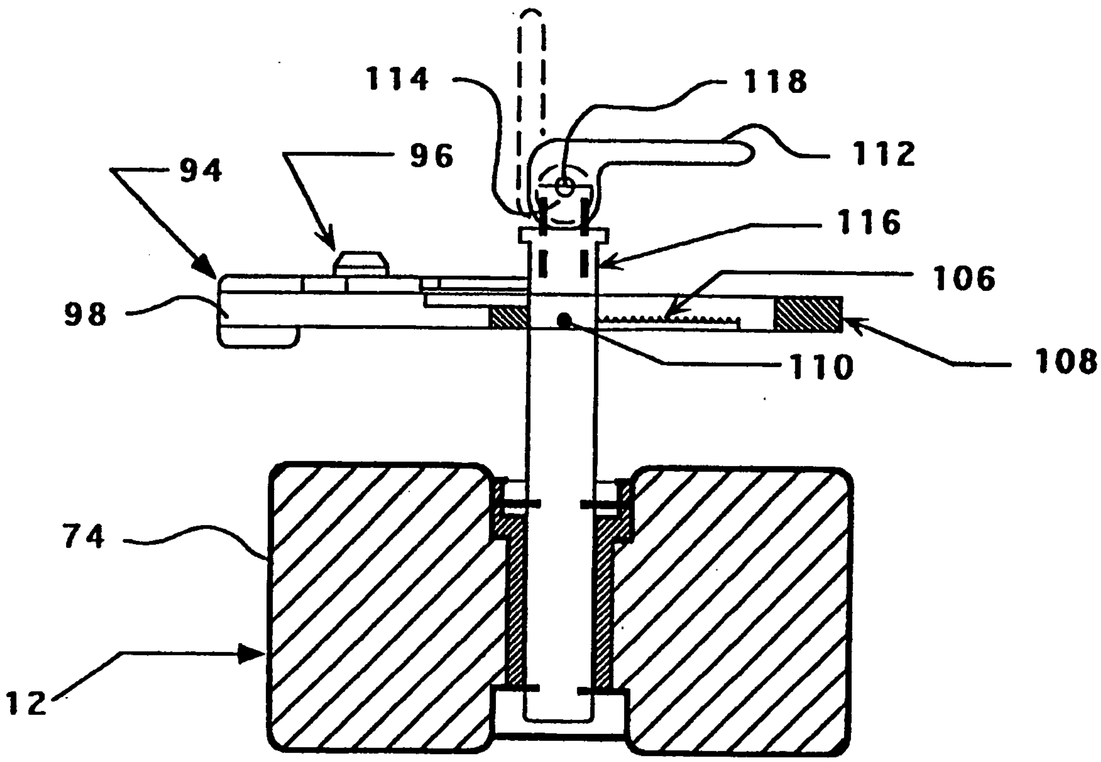

Fig. 10

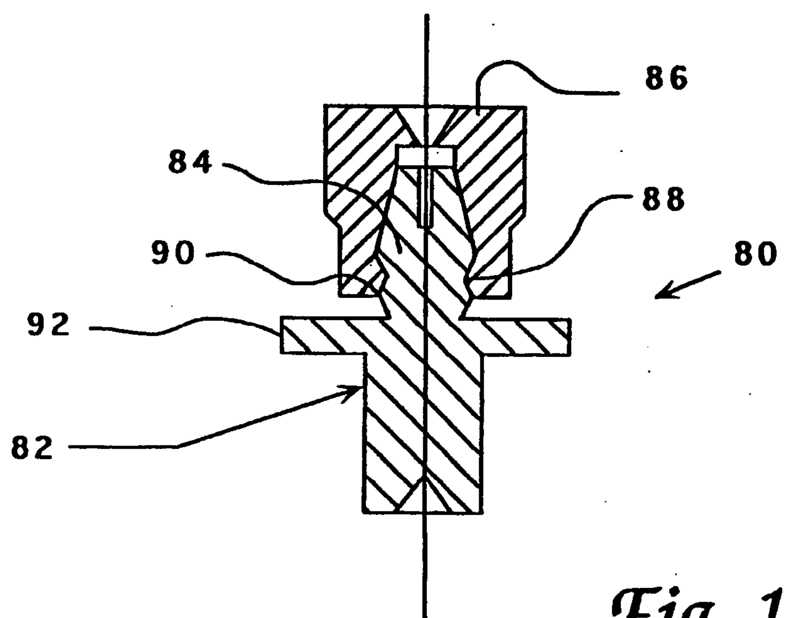

Fig. 11

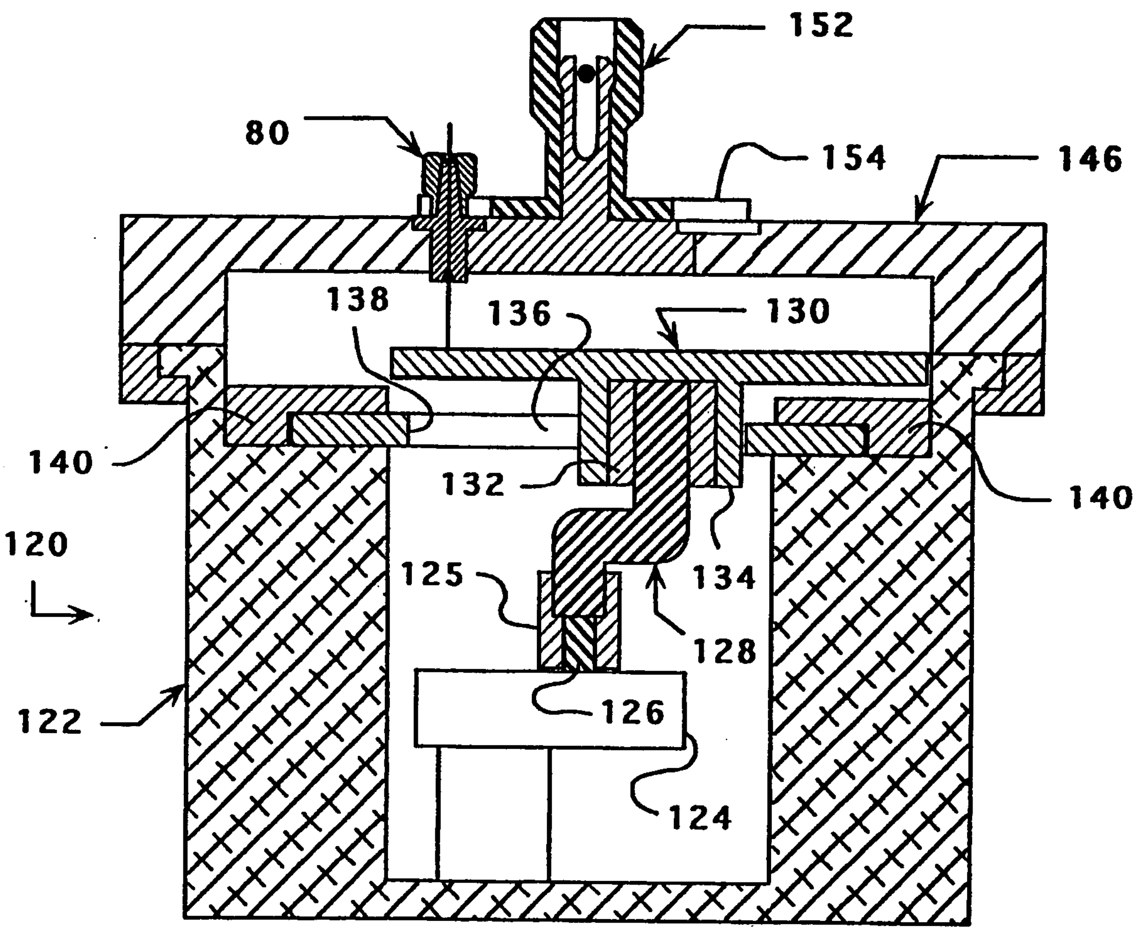
152
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Fig. 12

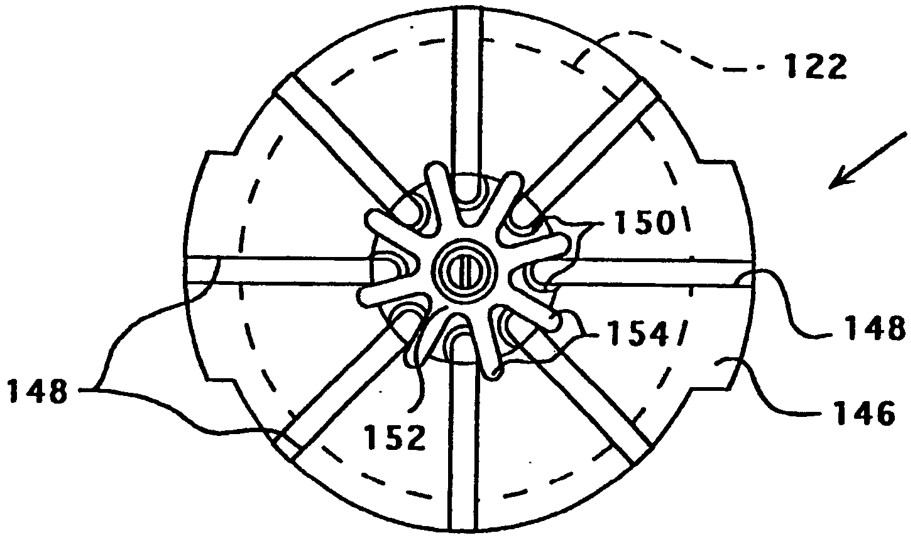

Fig. 13

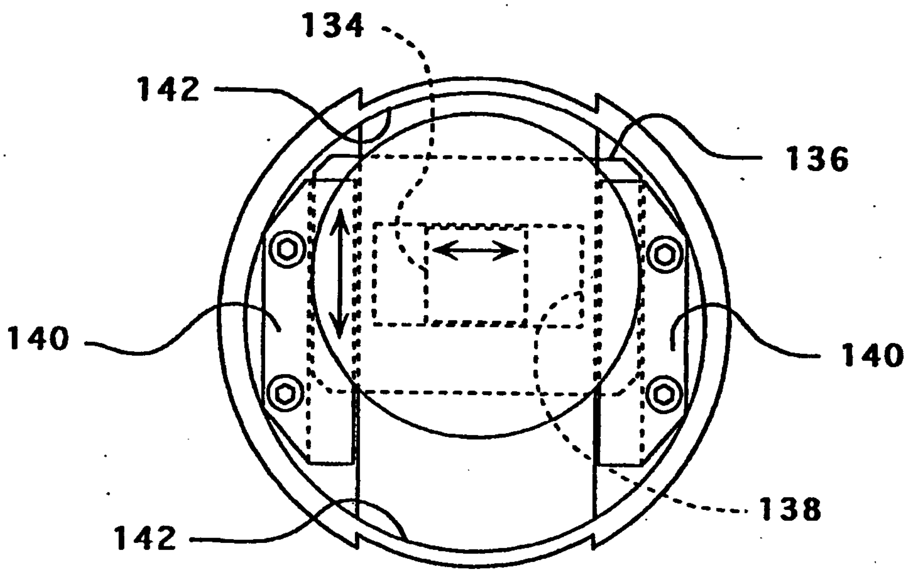

Fig. 14

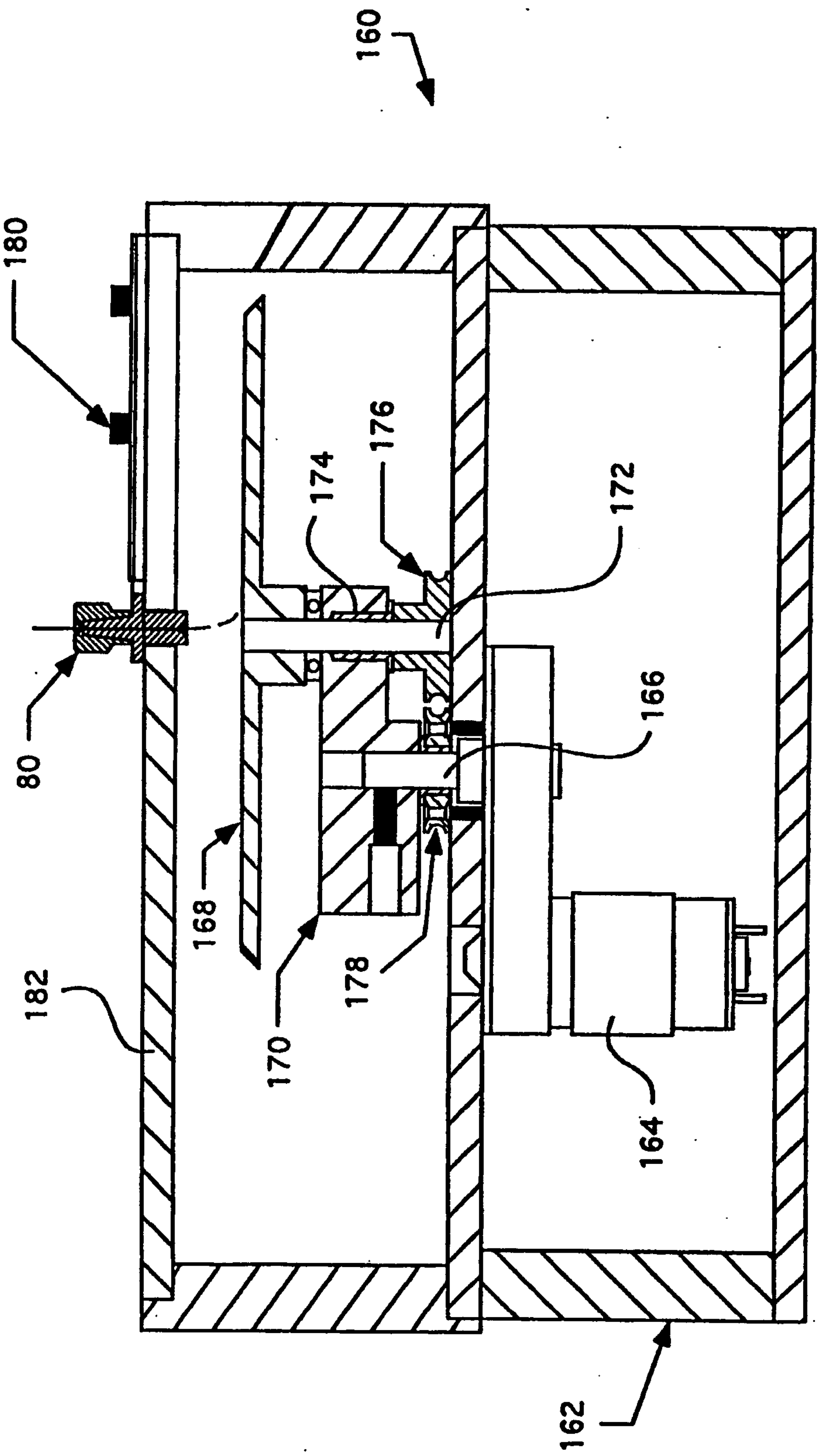

Fig. 15

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 94/08605

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24B19/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 294 650 (TEKTRONIX INC.) 14 December 1988 see claims; figures	1,14
A	WO,A,88 04217 (ENGIS LTD.) 16 June 1988 see page 8, line 17 - page 9, line 16; figures 6,7	1,14
A	EP,A,0 529 939 (TOTOKU ELECTRIC CO. LTD.) 3 March 1993 see page 7, column 11, line 17 - line 57; figure 12	1,14
A	WO,A,90 09207 (SIMONS R.) 23 August 1990	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
28 November 1994	19.12.94
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Eschbach, D

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. ...nal Application No
PCT/US 94/08605

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0294650	14-12-88	US-A-	4818263	04-04-89
		JP-A-	1071659	16-03-89
WO-A-8804217	16-06-88	AU-A-	1040388	30-06-88
EP-A-0529939	03-03-93	JP-A-	5181034	23-07-93
		US-A-	5245684	14-09-93
WO-A-9009207	23-08-90	NL-A-	8900334	03-09-90
		AU-A-	5090590	05-09-90